Journal of Agricultural Science; Vol. 10, No. 4; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Macronutrients and Micronutrients Variability in Soybean Seeds

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Received: October 30, 2017 Accepted: January 4, 2018 Online Published: March 15, 2018

doi:10.5539/jas.v10n4p209 URL: https://doi.org/10.5539/jas.v10n4p209

Abstract

The objective of this work was to evaluate the chemical composition of the macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), and micronutrients: boron (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn), and the elements aluminum (Al) and sodium (Na) measured in soybean seeds from different producing regions of Brazil. This work was carried out by sampling 2543 lots of soybean seeds produced in the 2009, 2010, 2011 and 2012 growing seasons. There is high variability of macro and micronutrients concentration in soybean seeds produced in several regions of Brazil. The nitrogen, potassium, phosphorus, and calcium are the most pronounced macronutrients in soybean seeds. Among the micronutrients, iron, manganese and zinc are those with more evidence. Understanding macro and micronutrients variability is critical for improving management and fertility treats in soybean seed production fields.

Keywords: nutritional composition, minerals, interrelations

1. Introduction

Soybean cultivation is widely distributed in Brazil, as the country is the second largest producer of this crop in the world. The study about quality of soybean seeds has increased in the last years, considering its importance for establishing the field (Carvalho et al., 2015). Soybeans production in the 2016/2017 harvest was over 114 million tons in an area of 33 million hectares (CONAB, 2017).

The increase in soybean production in Brazil is due to technologies and inputs employed, which allow the cultivar to express its genetic and physiological potential (Demari et al., 2016). The advances achieved through genetic breeding are transferred to farmers by the seeds, therefore, high yielding fields begin with an adequate stand of plants, which depends on the utilization of high quality seeds (Szareski et al., 2016). The term seed quality is defined as a set of characteristics that determine their value for sowing, and their performance potential can only be consistently identified when considering the interactions among genetic, physical, physiological and sanitary attributes (Peske et al., 2012).

Among the factors affecting seed quality, it may be mentioned the availability of nutrients in the soil, since seeds with adequate nutrient content have high capacity to generate vigorous and productive plants (Pelegrin et al., 2016). Thus, seeds should be produced in areas with high nutrient availability to the plants, achieving not only higher yields but also seeds of better quality (Marcos Filho, 2015).

The reserve substances contained in seeds are responsible for supplying the energy and minerals necessary to fully manifest their vital functions, as well as affecting their storage potential (Meier et al., 2016). The macro and micronutrients contained in the seeds are necessary for seedlings development and establishment in the field (Magalhaes et al., 2015). Thus, seeds with high content of certain macro or micro nutrient may originate vigorous plants even in soils with deficiency of this nutrient. However, seed reserves are only enough to guarantee seedling emergence, and from this stage, the plant initial development in the field will mainly depend on soil fertility (Carvalho & Nakagawa, 2012; Carvalho et al., 2016).

Studies regarding seeds chemical composition are of practical interest for seed technology, since their physiological quality is characterized by influence seedlings initial development, biological nitrogen fixation in leguminous, and consequently the establishment of their initial stand in the field, as nutrient deficiency may lead to disorganization of initial metabolic processes up to grain yield (Coelho et al., 2002; Carvalho et al., 2017). The objectives of this work was to evaluate the chemical composition of the macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), and micronutrients: boron (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn), and the elements aluminum (Al) and sodium (Na) measured in soybean seeds from different producing regions of Brazil.

2. Material and Methods

This work was carried out by sampling 2543 lots of soybean seeds produced in the 2009, 2010, 2011 and 2012 growing seasons. The seed lots were sampled through the Seed Analysis Laboratory of the company Dimicron Química do Brasil Ltda®, in Cruz Alta - RS, Brazil. Posteriorly, they were sent to the Laboratory of Chemical Analysis of the Brazilian Institute of Analyzes located in Sumaré, SP. The study was based on a descriptive approach of 2543 seed lots, where 50 grams of seeds were sampled for each chemical determination of nutrients and elements (Malavolta, 1989). It was affeered the macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), Sulfur (S), the micronutrients: Boron (B), Copper (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn), and the elements Aluminum (Al) and Sodium (Na), being them.

Nitrogen (N): The semi-micro-Kjeldahl method was used based on the transformation of the ammoniacal nitrogen $(NH_4)_2SO_4$ into ammonia (NH_3), which is fixed by boric acid and then titrated with H_2SO_4 until a new formation of $(NH_4)_2SO_4$ in the presence of acid and base indicator, results in grams per pound of seeds (g kg^{-1}).

Phosphorus (P): Determined by metavanadate colorimetry based on the formation of a yellow compound of the vanadomolibo phosphoric system in acidity from 0.2 to 1.6 N.A., with its color developed by photocolorimeter or spectrophotometer using a color filter complementary to the sample, measuring the percentage of transmission (% T), absorbance (A) or optical density (O.D.), results in grams per kilogram of seeds (g kg^{-1}).

Potassium (K): Obtained by atomic absorption spectrometry through the oxidation of the plant material by nitric-perchloric digestion, and then quantified by atomic absorption spectrophotometer with K-(Lc) hollow cathode lamp, results in grams per kilogram of seeds (g kg^{-1}).

Calcium (Ca) and Magnesium (Mg): Measured by atomic absorption spectrophotometry for calcium and magnesium, using a calcium-magnesium or individual discharge arc lamp (or hollow cathode), being necessary the addition of lanthanum or strontium to prevent the interference caused by phosphates and aluminum, results in grams per kilogram of seeds (g kg^{-1}).

Sulfur (S): Determined through sulfate turbidimetric based on the turbidity formed by sulfur precipitation by barium chloride, in the form of barium sulfate, turbidity measured in a colorimeter or spectrophotometer in the form of transmittance (T) or absorbance (A or D.O.), results in grams per kilogram of seeds (g kg^{-1}).

Boron (B): Determined through H azomethine colorimetry, using the formation of a colored complex by the reaction of boric acid with the reagent H azomethine, results in grams per kilogram of seeds (g kg^{-1}).

Copper (Cu): Obtained through atomic absorption spectrophotometry with scale expansion due to its low concentration in plants, results in grams per kilogram of seeds (g kg^{-1}).

Iron (Fe): Measured by atomic absorption spectrophotometry, results in grams per kilogram of seeds (g kg^{-1}).

Manganese (Mn): Determined by atomic absorption spectrophotometry using the appropriated hollow cathode lamp, results in grams per kilogram of seeds (g kg^{-1}).

Zinc (Zn): Obtained through atomic absorption spectrophotometry using the appropriated hollow cathode lamp, results in grams per kilogram of seeds (g kg^{-1}).

Sodium (Na): Measured by atomic absorption spectrophotometry using a respective hollow cathode lamp, results in grams per kilogram of seeds (g kg^{-1}).

Aluminum (Al): Determined by colorimetry of aluminum by dry matter oxidation through incineration process, measuring the color developed in spectrophotometer, results in grams per kilogram of seeds (g kg^{-1}).

The data were submitted to a descriptive analysis for each measured trait, in order to determine the distribution frequency, amplitude and number of classes formed by each nutrient and elements measured in 2543 lots of soybean seeds.

3. Results and Discussion

3.1 Nitrogen (N)

This mineral is highly required by plants, being available in the soil as ammonium, nitrate, aminoacids, peptides and complex insoluble forms. Plant species differ in their preference for nitrogen sources, where they mainly absorb inorganic forms such as nitrate (NO_3^-) or ammonium (NH_4^+) (Williams & Miller, 2001). This element is closely linked to the production of important constituent proteins for embryo initial development during seeds germination, with great effects on grain yield. For grain filling, two sources of nitrogen are used, one originated from soil absorption and the other from remobilization of vegetative tissues (Ta & Weiland, 1992).

In case of abiotic stresses due to drought or nitrogen deficiency, there is a possibility of remobilizing this element from vegetative tissues to the grains (Ta & Weiland, 1992; Carvalho et al., 2013). Research by Carvalho and Nakagawa (2012) defines that nitrogen influence seeds physiological quality, however their effects depend on environmental conditions and plant development stage. Nitrogen levels (N) evidenced for the 2543 soybean seed lots presented a maximum value of 95 g kg^{-1} and a minimum of 22 g kg^{1}, representing an amplitude of 73 g kg^{-1} (Figure 1). In a soybean seeds production system, it is estimated that about 57.82 kg of nitrogen are exported for producing one ton of seeds (Borket, 1986).

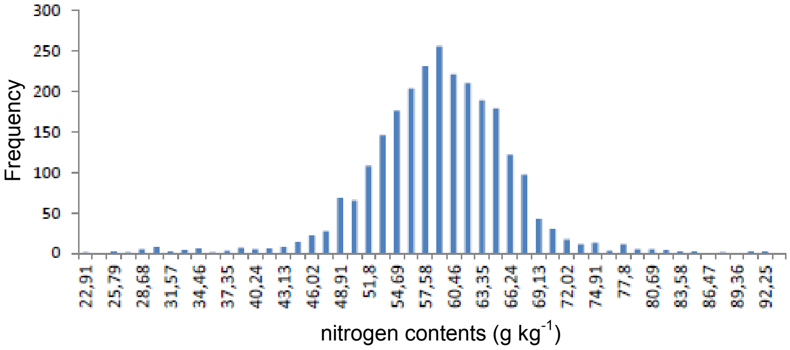

Figure 1. Frequency distribution histogram for nitrogen contents in 2543 soybean lots, expressed in g kg^{-1}

3.2 Phosphorus (P)

This nutrient is involved in energy transference (ATP) necessary for photosynthesis, translocation and metabolic processes (Shuman, 1994; Ferrari et al., 2014). It participates in the formation of reproductive structures, root development, fruit and seed formation (Raij, 1991; Follmann et al., 2014). The plant's reserve phosphate is in organic form as phytin in the seeds, and as inorganic form in vegetative tissues (Butler & Jones, 1973). Research on several species shows that seedlings dry matter and plant production may increase with higher phosphorus levels in the seeds. It might occur in the absence or presence of phosphate fertilization (Bolland & Baker, 1989). In situations of nutritional deficiency, the magnitudes of this nutrient tend to reduce biomass accumulation and soybean seed yield (Mengel & Kirkby, 1987; Carvalho et al., 2015).

The increase of phosphorus concentration in the seeds improves phosphorus supplying for plants in early developing stages (Grant et al., 2001). According to Trigo et al. (1997), plants from seeds with higher phosphorus content improve their initial metabolic demand, as evidenced by tests such as first germination counting, seeding emergence at field, root length and aerial part. Among macronutrients, phosphorus is required in smaller quantities by soybean, and the amount of phosphorus applied to the soil, generally exceeds its extraction by the crop, in contrast, nitrogen (N) and potassium (K) differ in demand, and have a close relationship with productivity (Raij, 1991; Szareski et al., 2015).

The phosphorus content (P) in soybean seed lots had a maximum value of 10 g kg^{-1} and a minimum of 0,44 g kg^{-1}, with a range of 9.56 g kg^{-1} in relation to maximum and minimum accumulations (Figure 2). In a soybean production system, for producing one ton of seeds, about 3.74 kg ha^{-1} of phosphorus is exported in the harvest. Research with 1200 soybean lots from different regions of Brazil define an export of 10 kg ha^{-1} of P_2O_5 (Borket, 1986), generally about 75% of the mineral phosphorus applied at sowing is exported to soybean seeds (Bataglia & Mascarenhas, 1977; Pauletti, 2004; Ferrari et al., 2015).

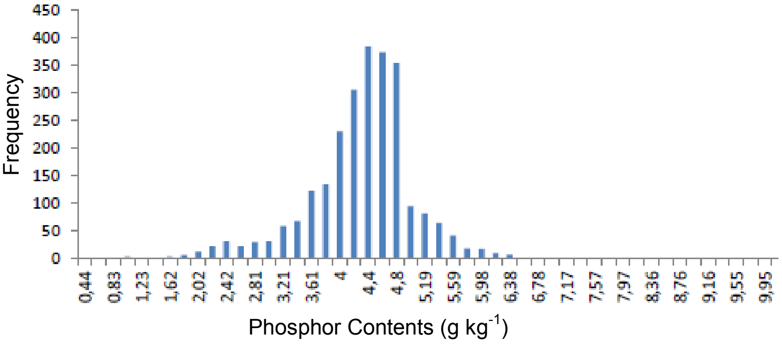

Figure 2. Frequency distribution histogram for phosphor contents in 2543 soybean lots, expressed in g kg^{-1}

3.3 Potassium (K)

This nutrient is predominantly found as free or adsorbed cation, and it may be easily translocated along cells or tissues in the plant (Lindhauer, 1985). This high mobility in the plants is due to functions and characteristics of this nutrient, which is the main cation used for neutralizing osmotic loads and actions (Clarkson & Hanson, 1980; Souza et al., 2015). An adequate potassium nutrition promotes the increases in protein content, reserve carbohydrates, coloration, aroma, C vitamin content, soluble solids, and minimizes physiological disorders (Usherwood, 1985; Koo, 1985; Souza et al., 2015). The requirements of this nutrient for an adequate growth and development of plants are between 20 and 50 g kg^{-1} of dry tissues, however, soybean plants have the capacity of absorbing potassium amounts higher than their needs (Meurer, 2006).

Potassium (K) contents for the soybean seed lots presented maximum magnitudes of 52 g kg^{-1} and minimum of 1 g kg^{-1}, resulting in an amplitude of 51 g kg^{-1} between the extremes (Figure 3). In a soybean seeds production system, for each ton of seed produced, 18.42 kg ha^{-1} of potassium is exported. Research with 1200 samples of plant tissue and soybean seeds from several growing environments in Brazil reveal that one ton of seeds exported about 20 kg ha^{-1} of K_2O (Bataglia & Mascarenhas, 1977; Borket, 1986; Pauletti, 2004).

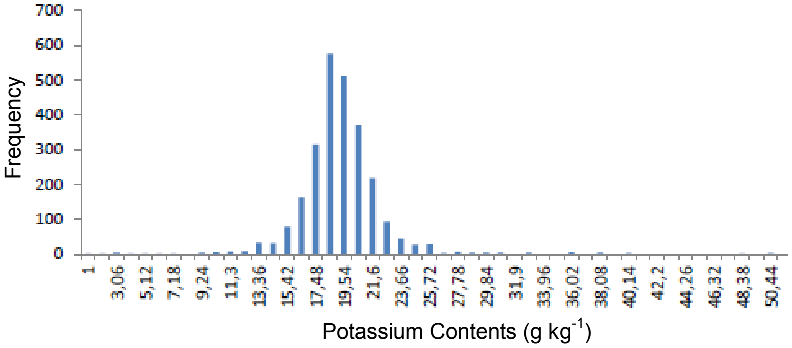

Figure 3. Frequency distribution histogram for potassium contents in 2543 soybean lots, expressed in g kg^{-1}

3.4 Magnesium (Mg)

This element is responsible for enzymatic activation of several metabolic complexes, it is activator of enzymes related to the synthesis of carbohydrates and nucleic acids, active enzymes involved in respiration, photosynthesis, DNA and RNA synthesis, and structural arrange of the chlorophyll molecule (Taiz & Zeiger, 2009), and an integral part of phytin (Ca and Mg salt of phosphoric inositol) that accumulates in seeds (Neptune, 1986). For an adequate growth and development of soybeans, the availability of 1.5 to 3 g kg^{-1} of fertilizer is prioritized (Vitti, 2006). Magnesium (Mg) contents available in 2543 soybean seed lots showed a maximum of 24 g kg^{-1} and a minimum of 0.65 g kg^{-1}, with a range of 23.35 g kg^{-1} between the extremes verified for this nutrient (Figure 4). In a soybean production system, it is considered that for the production of one ton of seeds, about 1.91 kg ha^{-1} of magnesium will be exported in the harvest (Bataglia & Mascarenhas, 1977; Borket, 1986; Kavalco et al., 2015).

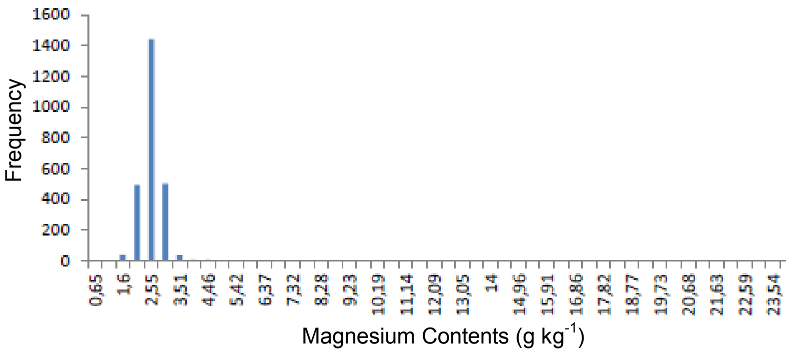

Figure 4. Frequency distribution histogram for magnesium contents in 2543 soybean lots, expressed in g kg^{-1}

3.5 Calcium (Ca)

This element takes place in the synthesis of cell-wall and middle lamella, separating newly divided cells (Taiz & Zeiger, 2009). Calcium-rich soils with balanced fertilization result in better conformities of soybean and bean seed tegument, being more vigorous and tolerant to mechanical damages (Peske et al., 2012). Plants have developed mechanisms to restrict Ca transport, keeping low concentrations of this nutrient in phloem cells or precipitated as oxalate along sieve tubes and seed tegument (Mix & Marschner, 1976; Fink, 1991), being indispensable for germination of pollen grains, pollen tube growth and wall synthesis (Malavolta, 1980; Carvalho et al., 2015). Calcium is required for the functioning of plant membranes, characterized as a secondary messenger of plant responses to environmental and hormonal effects (Adams et al., 1993; White & Broadley, 2003). The calcium contents (Ca) for 2543 soybean seed lots expressed maximum values of 32 g kg^{-1} and minimum of 0.25 g kg^{-1}, with amplitude of 1.75 g kg^{-1} (Figure 5). In a soybean seed production system, for harvesting one ton of seeds, about 1.8 to 3.0 kg ha^{-1} of calcium is exported by the crop (Bataglia & Mascarenhas, 1977; Borket, 1986; Szareski et al., 2016).

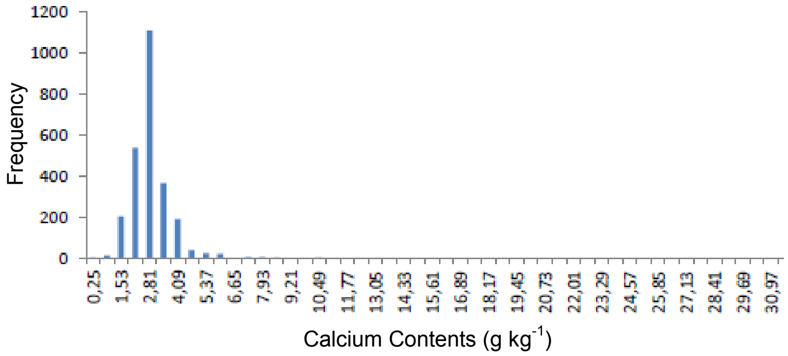

Figure 5. Frequency distribution histogram for calcium contents in 2543 soybean lots, expressed in g kg^{-1}

3.6 Sulfur (S)

Constituent of amino acids as cysteine and methionine, coenzymes and vitamins (acetyl coenzyme A, S-adenosyl methionine, biotin, B1 vitamin, pantothenic acid), which are essential for plant metabolism (Vitti, 1986; Taiz & Zeiger, 2009). Studies have shown that 1 to 5 g of S per kilogram of plant dry matter are required for soybean growth and development, whereas cruciferous species demand 11 and 17 g kg^{-1} of sulfur (Vitti, 2006). The sulfur content (S) presented in the 2543 soybean seed lots showed maximum magnitude of 6 g kg^{-1} and a minimum of 0.14 g kg^{-1}, with an amplitude of 5.46 g kg^{-1} between the observed extremes (Figure 6). For each ton of seed produced, 1.98 to 5.4 kg ha^{-1} of sulfur are exported in the seeds (Borket, 1986; Olivoto et al., 2016).

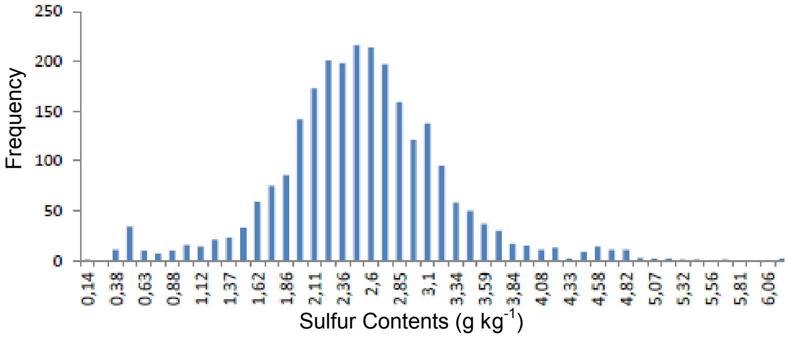

Figure 6. Frequency distribution histogram for Sulfur contents in 2543 soybean lots, expressed in g kg^{-1}

3.7 Boron (B)

This nutrient acts in cell division and differentiation, carbohydrates metabolism and transport, it also aids in the synthesis of cell-wall compounds, reproductive process, pollination, pollinic tube growth and seed production (Coetzer et al., 1990). Its deficiency is related to low germination of soybean seeds (Szareski et al., 2016). Suitable concentrations are defined ranging between 30 and 50 mg kg^{-1}, as this amplitude allows the normal seed growth and development (Malavolta et al., 1989; Sá, 1994; Pais & Jones Junior, 1996; Furlani, 2004). Boron levels (B) in 2543 lots of soybean seeds expressed maximum magnitudes of 89 mg kg^{-1} and minimum of 0.01 mg kg^{-1}, providing an amplitude of 88.99 mg kg^{-1} (Figure 7). For seed production fields, it is evident for each ton of seeds produced, an amount up to 5.68 g ha^{-1} of boron is exported in the harvest (Bataglia & Mascarenhas, 1977; Borket, 1986; Zimmer et al., 2016).

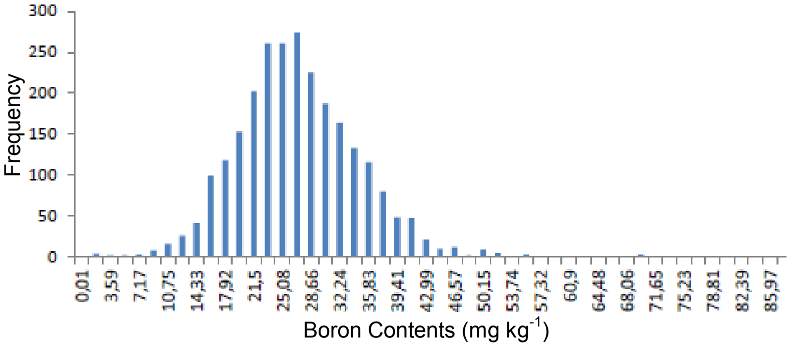

Figure 7. Frequency distribution histogram for boron contents in 2543 soybean lots, expressed in mg kg^{-1}

3.8 Copper (Cu)

Nutrient required at low concentrations, with slow mobility in plants, however possible of being translocated from vegetative structures to seeds. Deficiency of this element may result in non-viable pollen grains (Marschner, 1986; Carvalho et al., 2016). It associates to determining enzymes for redox reactions, which oxidize Cu^+ Cu^{2+}, acting in the transport of electrons during photosynthetic reactions (Haehnel, 1984). Concentrations of 2 to 75 mg of cooper per kilogram of dry matter is prioritized, with optimum range from 5 to 20 mg kg^{-1} for adequate plant growth and development (Malavolta et al., 1989; Pais & Jones Junior, 1996; Furlani, 2004). The copper (Cu) contents expressed by 2543 soybean seed lots had a maximum of 74 mg kg^{-1} and a minimum of 0.5 mg kg^{-1}, with an amplitude of 73.5 mg kg^{-1} (Figure 8). In soybean production systems, 16.80 to 18.7 g ha^{-1} of copper (Bataglia & Mascarenhas, 1977; Borket, 1986) is exported for each ton of seed produced.

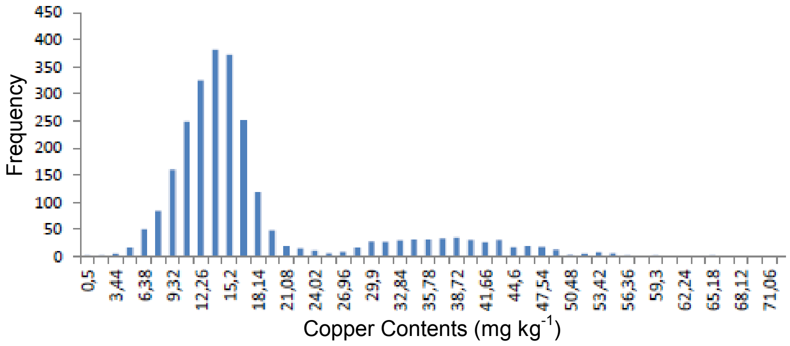

Figure 8. Frequency distribution histogram for copper contents in 2543 soybean lots, expressed in mg kg^{-1}

3.9 Iron (Fe)

It composes 5% of the entire earth's crust and is the second most abundant mineral element (Mengel & Kirkby, 1987). Among its functions, iron acts as enzymatic activator, participates in oxidation reactions (cytochromes, leguemoglobin, catalase, peroxidase, superoxide dismutase) and is part of proteins. Its concentration varies from 10 to 1500 mg kg^{-1} of the plant's dry matter, this magnitude varies according to the part of the plant, species and growing environment (Malavolta et al., 1989; Pais & Jones Junior, 1996; Furlani, 2004). The iron contents (Fe) obtained in 2543 seed lots of soybean presented a maximum of 900 mg kg^{-1} and a minimum of 10 mg kg^{-1}, characterizing a large amplitude of 890 mg kg^{-1} between the extremes (Figure 9). In soybean seed production systems, it is estimated that 83.20 to 114 g ha^{-1} of iron is exported at harvest for each ton of seed produced (Bataglia & Mascarenhas, 1977; Borket, 1986; Dellagostin et al., 2016).

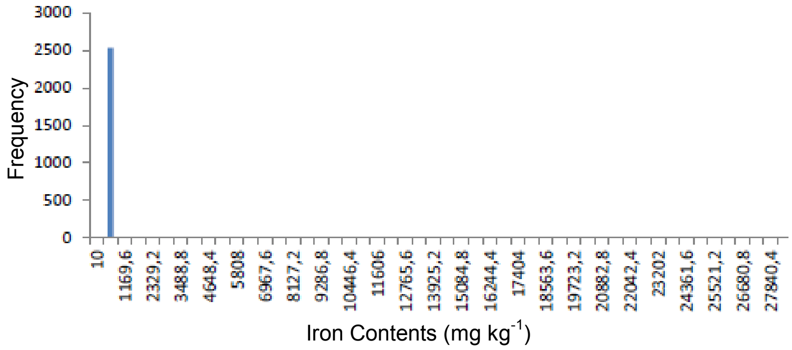

Figure 9. Frequency distribution histogram for iron contents in 2543 soybean lots, expressed in mg kg^{-1}

3.10 Manganese (Mn)

Nutrient involved in photosynthesis (photosystem II), taking place in the reaction enzymes which catalyze the initial stages of oxygen production (Marschner, 1986). Malavolta et al. (1997) defines that manganese has functionality in the cell elongation process and is related to tissue lignification (Marschner, 1995), providing impermeability to cellular wall (Mcdougall et al., 1996), effects on the capacity and speed of water absorption by the tegument, release of leachate during seeds imbibition in the germination process (Dubal et al., 2016). The concentrations of Mn in the plants vary from 5 to 1500 mg kg^{-1} of Mn in their dry matter, in contrast, the adequate concentrations are between 20 and 500 mg kg^{-1}, which allow the best conditions for plants growth and development (Malavolta et al., 1989; Pais & Jones Junior, 1996; Furlani, 2004). The manganese (Mn) contents evidenced in this study with 2543 lots of soybean seeds revealed maximum magnitudes of 455 mg kg^{-1} and a minimum of 5 mg kg^{-1}, with amplitude of 450 mg kg^{-1} (Figure 10). In seed production fields, it is defined that 38.95 g ha^{-1} of manganese are exported for each ton of seed produced (Bataglia & Mascarenhas, 1977; Borket, 1986).

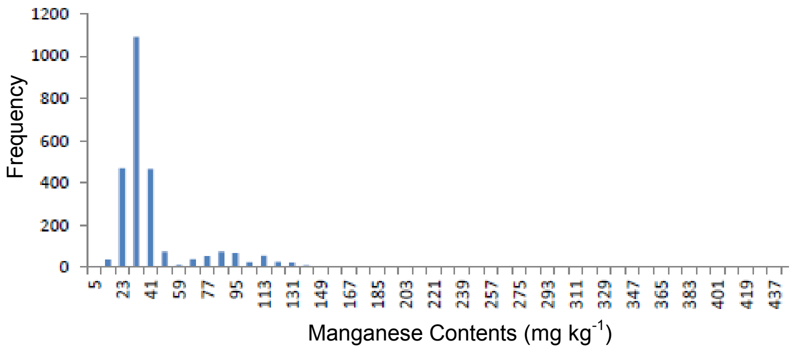

Figure 10. Frequency distribution histogram for manganese contents in 2543 soybean lots expressed in mg kg^{-1}

3.11 Molybdenum (Mo)

It acts on the biological process of nitrogen fixation, catalyzing the nitrogenase enzyme, which transforms atmospheric nitrogen into ammonia, acting together with the nitratoreductase enzyme, which assimilates nitrate in the plants (Taiz & Zeiger, 2009). Besides its importance in biological nitrogen fixation process, molybdenum is characterized as the micronutrients most demanded by soybean, with great effects on seed productivity (Vargas & Hungria, 1997; Broricket et al., 1992). Research by Guerra et al. (2006), observed that molybdenum and cobalt, when added to seeds, increase physiological quality and seed emergence (Jacob-Neto et al., 1988). The concentrations of Mo in plants vary from 0.01 to 500 mg kg^{-1} of dry matter, with adequate fractions of 0.6 and 10 mg kg^{-1} (Pais & Jones Junior, 1996; Furlani, 2004; Strobel et al., 2016). The molybdenum (Mo) contents expressed in the 2543 soybean seed lots showed a maximum of 179 mg kg^{-1} and a minimum of 0.02 mg kg^{-1}, with amplitude of 178.98 mg kg^{-1} (Figure 11). It is estimated that, for each ton of seeds produced, 1.95 g ha^{-1} of molybdenum are exported at harvest (Bataglia & Mascarenhas, 1977).

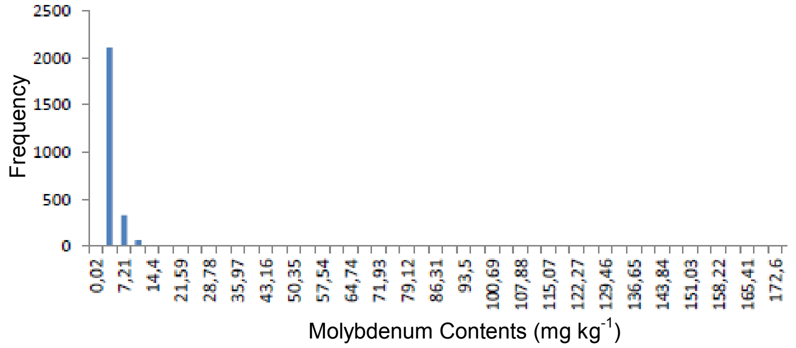

Figure 11. Frequency distribution histogram for molybdenum contents in 2543 soybean lots, expressed in mg kg^{-1}

3.12 Zinc (Zn)

This nutrient is absorbed in the form of Zn^{2+}, through the roots and leaves, presents intermediate mobility (Dechen & Nachtigall, 2006). Plants grown under zinc deficiency produce seeds with low concentrations of this nutrient, seedlings are less vigorous and seed productivity is altered (Rengel & Graham, 1995; Genc et al., 2000). The concentrations of Zn may range from 3 to 150 mg kg^{-1} of plant dry matter (Malavolta et al., 1989; Pais & Jones Junior, 1996; Furlani, 2004; Pelegrin et al., 2016). The zinc contents (Zn) for 2543 soybean seed lots evidenced maximum magnitude of 485 mg kg^{-1} and minimum of 3 mg kg^{-1}, representing an amplitude of 482 mg kg^{-1} (Figure 12). For soybean seeds production, an export of 36.12 g ha^{-1} of zinc is considered for each ton of seeds harvested (Borket, 1986).

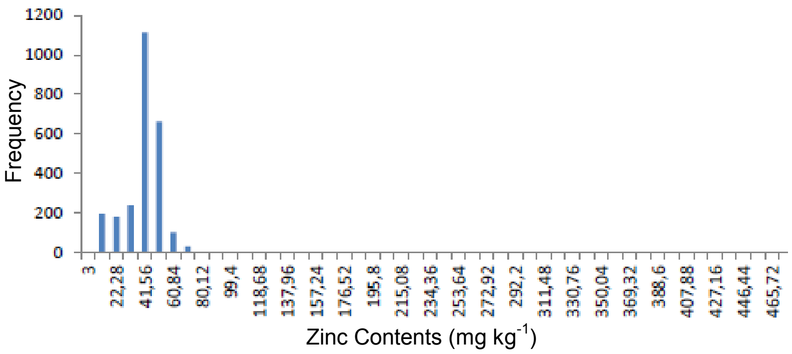

Figure 12. Frequency distribution histogram for zinc contents in 2543 soybean lots, expressed in mg kg^{-1}

3.13 Sodium (Na)

Characterized as an element poorly absorbed in ionic form, however its main purpose for plants mineral nutrition is to substitute (95%) potassium in certain physiological, metabolic and osmotic functions (Marschner, 1995). The levels of sodium (Na) in 2543 soybean seed lots showed a maximum of 475 mg kg^{-1} of seeds and a minimum of 0.5 mg kg^{-1} (Figure 13), with an amplitude of 574.5 mg kg^{-1}.

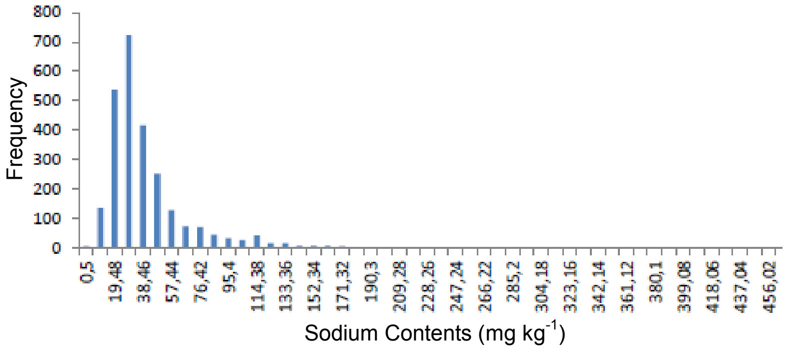

Figure 13. Frequency distribution histogram for sodium contents in 2543 soybean lots, expressed in mg kg^{-1}

3.14 Aluminum (Al)

The 2543 soybean seed lots evidenced large magnitudes, with 3800 mg kg^{-1} and minimum of 5 mg kg^{-1} thus, it was possible to verify an amplitude of 3795 mg kg^{-1} (Figure 14).

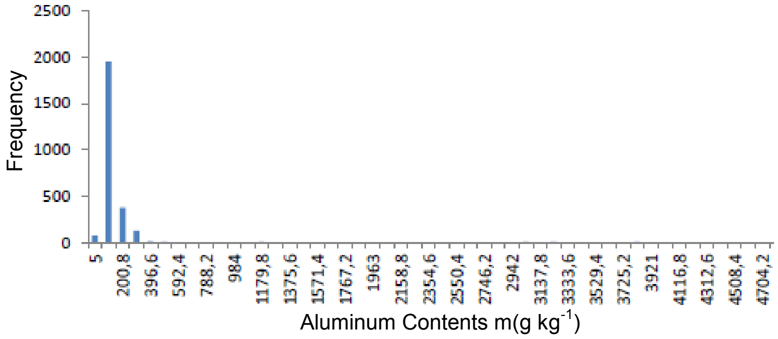

Figure 14. Frequency distribution histogram for aluminum contents in 2543 soybean lots, expressed in mg kg^{-1}

The most important macronutrients for soybean seeds production were nitrogen (57.82 g kg^{-1}), potassium (18.42 g kg^{-1}), phosphorus (3.74 g kg^{-1}), calcium (2.24 g kg^{-1}), sulfur (1.98 g kg^{-1}) and magnesium (1.91 g kg^{-1}). However, the most demanded and exported micronutrients for soybean seeds production were iron (83.20 mg kg^{-1}), manganese (38.93 mg kg^{-1}), zinc (36.12 mg kg^{-1}), boron (25.68 mg kg^{-1}), copper (16.80 mg kg^{-1}), molybdenum (1.95 mg kg^{-1}) and sodium (35.43 mg kg^{-1}). Nitrogen and potassium were the most required nutrients for soybeans, followed by phosphorus, sulfur, calcium and magnesium. Phosphorus was more translocated (65%), followed by nitrogen (61%), potassium (53%), sulfur (35%), magnesium (30%) and calcium (25%). The micronutrient with the highest translocation was molybdenum (71%), zinc (66%), chlorine (46%), copper (38%), boron (26%), manganese (23%) and iron (15%) (Sfredo, 2008). Determining the concentration of each nutrient and their dynamics for soybean seeds development is of fundamental importance for improving fertility management and fertilization recommendations in seed production areas, seeking not only for the largest production, but for the increase in physiological quality and maximum efficiency of the seeds at field conditions.

4. Conclusion

There is high variability of macro and micronutrients concentration in soybean seeds produced in several regions of Brazil. Nitrogen, potassium, phosphorus, and calcium are the most pronounced macronutrients in soybean seeds. Among the micronutrients, iron, manganese and zinc are those with more evidence. Understanding macro and micronutrients variability is critical for improving management and fertility treats in soybean seed production fields.

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